PRESERVICE TEACHERS' USE OF NOTICING PRACTICES TO EVALUATE TECHNOLOGICAL RESOURCES

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This study examines how elementary preservice teachers notice children's mathematical thinking and how this noticing influences the evaluation of technological resources. In particular, we explore the aspects of thinking to which preservice teachers attend and how they interpret evidence about children's thinking when using the Spatial-Temporal Math (ST Math) program. Data collection included a group survey administered after an initial exploration of a set of ST Math activities, screencast recordings during which children used and talked about the program, and a reflective writing assignment. The findings of this study show how preservice teachers used their noticing skills (attending and interpreting) in their evaluations of the tool, in some cases prompting them to shift their evaluation on the basis of student thinking.

Keywords: Teacher Education-Preservice, Technology, Instructional Activities and Practices

Introduction

Professional noticing (Jacobs, Lamb, & Philipp, 2010) is an important instructional practice, essential for supporting and extending students' mathematical thinking by focusing on in-the-moment decisions as well as on students' mathematical understanding. Recent studies have connected noticing to the use of technology, including technology evaluation (Smith, Shin, Kim, &, Zawodniak, 2018), technology-mediated teacher noticing (Walkoe, Wilkerson, & Elby, 2017), and developing noticing through the creation of animated teaching episodes (de Araujo et al., 2015). For example, Smith and his colleagues (2018) articulated a technological framework for the evaluation of technological tools by having preservice teachers (PSTs) engage with and reflect on the qualities of the tools. In this study, we build on this work by exploring 1) how PSTs notice the mathematical thinking of students as they engage with a particular tool, and 2) how this noticing influences their evaluation of the tool.

The technological resource we investigated was "Spatial-Temporal Mathematics" or ST Math, a game-based instructional software. We selected ST Math primarily because it was a tool that had been adopted by the district in which most of the PSTs in the program were placed for their junior-year field experience. District policy was that elementary students were to spend 90 minutes each week using ST Math. As a central focus of the mathematics methods course was noticing and responding to student thinking, we wanted to know how PSTs would use these skills in the context of the ST Math program.

ST Math is designed to use multiple dynamic representations of quantities and other mathematical objects to develop students' construction of mental images ahead in space and time (Peterson et al., 2004). In a previous analysis of student's engagement with ST Math, Yeo (2018) found that various ST Math activities ranged widely in their support for the development of mathematical concepts, with some activities providing strong connections to concepts and others requiring only surface level engagement.

This study shifts the focus from student thinking to PST noticing, exploring how novices make sense of student actions and speech when they are engaged with ST Math software. In particular, this study seeks to examine the following questions: (1) To what aspects of children's thinking do PSTs attend when the children are engaged in the ST Math activities, and how do the PSTs interpret evidence about this thinking? (2) How do PSTs draw on their noticing of children's thinking when evaluating the ST Math activities?

Theoretical Background

Teachers are aware of aspects of students' work in the classroom and they use this awareness to make pedagogical decisions (Goodwin, 1994). Awareness and sense-making of student's work have been described as *intentional noticing* (Mason, 2002) and were later expanded to include instructional responses and referred to as *professional noticing* (Jacobs et al., 2010). Professional noticing consists of three components: *attending* to student's mathematical ideas, *interpreting* their understanding, and *deciding how to respond* to their understanding. Studies have shown that PSTs can learn and develop these noticing skills through the support of teacher educators (Sherin & van Es, 2005), and that there are patterns in how PSTs apply the components (e.g., Wieman & Webel, 2019). The noticing framework has been extended to serve as a basis for a set of specific teaching moves (Jacobs & Empson, 2016), with the justification that one cannot act on information that one does not perceive. This idea is echoed in the establishment of "Elicit and use evidence of student thinking" as one of eight central teaching practice endorsed by the National Council of Teachers of Mathematics (2014). Noticing has also recently been extended to the evaluation of technological tools, such as interactive dynamic geometry activities (Smith et al., 2018). Previous studies have shown that teachers tend to evaluate online resources and activities positively with little consideration of mathematical or pedagogical features, but instead attended to surface level characteristic, such as whether students would be familiar with the problem types or if the activities had a game-like interface (e.g., Webel, Krupa, & McManus, 2015). In this study, we focus on how PSTs attend to and interpret children's thinking in the use of technological resources.

Methodology

The participants of this study were 21 elementary PSTs enrolled in a methods course at a Midwest university. Most participants were in their third year of a four-year program. The primary emphasis of the course was to understand how children's mathematical thinking develops in the domain of number and operations (Carpenter et al., 2014) and to develop the core teaching practices of eliciting and responding to children's thinking (Jacobs & Empson, 2016). Additionally, the PSTs engaged in daily one-to-one interactions with an assigned student in 3rd, 4th, or 5th grade (a "Math Buddy") during the whole semester.

In a series of course assignments, PSTs were first asked to explore a specified set of ST Math activities in small groups and respond to some reflection prompts. Then they later asked their Math Buddies, who were familiar with ST Math, to engage the same activities. PSTs were asked to elicit the child's thinking about the mathematics in the same tasks, and then finally to write a reflection paper about this experience. Three ST Math tasks (Figure 1) were chosen: *Pie Monster* (subtraction), *How Many Petals?* (place value), and *Building Expressions* (multiplication and division). These were selected to ensure that all of the children could engage in a developmentally appropriate task, and because, based on our previous engagement with ST Math, we believed they represented a range of opportunities for children to develop conceptual understanding. Specifically, the *Pie Monster* task involves whole number subtraction with various structures, such as start-unknown, change-unknown, and result-unknown (Carpenter et al., 2014) including three types of direct modeled representations. The screen (see Figure 1- left) uses two red-circles to represent the change (subtrahend), seven orange-circles to represent the start (minuend), and the white circles in the Monster's belly to represent the result (difference). When choosing the number of the white circles, JiJi (penguin character) attempts to cross the screen. If a provided answer is correct, the boxes are burnt by the Monster's fire and Jiji can cross the screen. If not, JiJi would go back to the starting place and one trial would be lost. The *How many petals?* task involves two-digit and three-digit place value concepts with the representations of petals (ones), flowers (tens), and a bunch of flowers (hundreds). Each tap on the 'ten' section on the screen (Figure 1-middle) collects ten petals, and so on for each place value. If the the 'ones' section has more individual petals than ten, a flower would be automatically made of the ten petals. Ten tens will automatically transform into a bunch of flowers (hundreds). The *Building Expressions* task involves the relationship between multiplication and division (e.g., 24 ÷ 4 = 6, 4 × 6= 24). A number of green dots must be selected according to the first number of a given number expression and the user decides how to drag the slider to partition the set of dots into the number of pink segments as designated by the second number. The quotient is the number of dots corresponding to each segment.

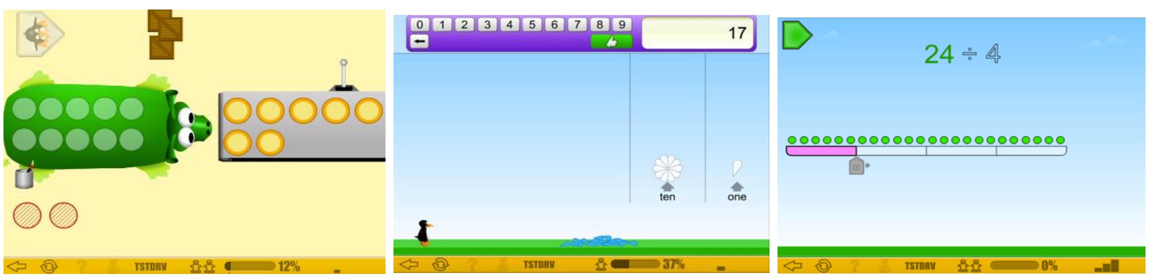

Figure 1: ***Pie Monster*** **(left),** ***How Many Petals?*** **(middle), and** ***Building Expression*** **(right)**

The data collected consisted of three parts: 1) "responses from the exploratory activity," in which groups of PSTs described, for each ST Math task, what mathematical ideas they believed the task was targeting, whether the task provided a "good opportunity" to learn those ideas, and what questions they would ask children to better understand their thinking while engaging in the task; 2) "screencasts" recorded while working with the Math Buddies, which captured manipulations on a tablet device and verbal explanations in real time; and 3) an individual reflection paper in which PSTs described the children's strategies, compared the strategies to how the children solved story problems, and gave an evaluation of each activity.

To address RQ1, PSTs' initial responses regarding the ST Math activities were categorized into *attending* and *interpreting*, and then additional data from reflection papers were coded similarly (see Table 1 for specific codes). In this analysis, we did not include the codes for *deciding how to respond* to focus on PSTs' evaluation of technological resources through the process of attending and interpreting. The screencasting data were reviewed to redefine and modify this coding scheme. Then, we examined responses from the exploratory activity to characterize each PST's initial evaluation of the ST Math activities. To address RQ2, this baseline was compared to their final reflection paper submitted after actually interacting with students. We noted whether the PSTs' evaluation of the ST Math activities changed, and how their noticing of student thinking appeared to influence their evaluation (or not).

Table 1: Noticing Coding Scheme in Exploratory and Reflective Phases

	Attending	Interpreting
Exploratory Phase	-Instructions -Visual representations -Manipulation -Mathematics concepts -Strategies	-Using sense-making to solve tasks -Potential mathematical concepts -Making a connection between representation and concept -Requirement of prior knowledge
Reflective Phase [additional codes]	-Task structures -Learning goals -Verbal explanations -Semiotic actions -Gamified features -Situated context	-Progression of problem-solving strategies -Solving tasks with given representations -Sequence of the tasks

Findings

In this section, we present our analyses of PST's attending to and interpreting children's mathematical thinking in the context of their ST Math explorations, focusing primarily on the *Pie Monster* task. We then discuss PST's noticing positive and negative features of ST Math in relation to potential learning opportunities for children, focusing primarily on the *How many Petals?* and *Building Expressions* tasks.

Attending to Children's Thinking

Attending refers to focusing on "noteworthy aspects of complex situations" (Jacobs et al., 2010, p. 172). PSTs understandably tended to pay more attention to student thinking when reflecting on their interactions with their Math Buddies, but they also showed evidence of noticing when reflecting on their own exploration of the ST Math tasks. That is, they anticipated how students would think about and solve the tasks, commenting on the instructions, the visual representations, ways the environment could be manipulated, the mathematical concepts in the tasks, and strategies students might use. For example, Group A attended to the instructions of the Pie Monster task (Figure 2), which represents whole number subtraction with various number choices.

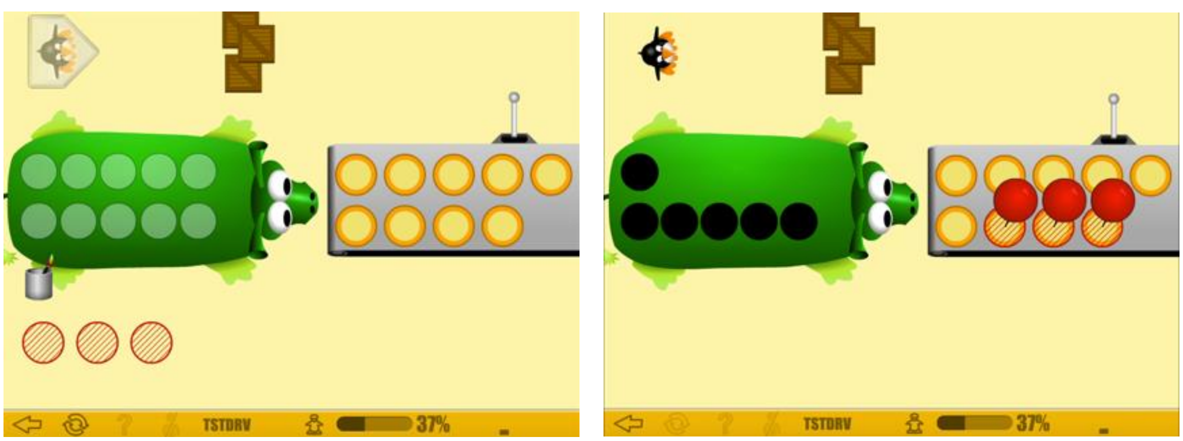

Figure 2: Problem Solving of the Pie Monster Task

This group noticed that the activity did not provide any instructions about how to play the game (this is a central design feature of ST Math). This unique feature of ST Math could lead to confusion about how to start and what they are supposed to do: "I feel like the game is simple but the instructions are not there and it can take them a while to figure out what numbers they need to subtract".

The initial attending pattern was expanded through one-to-one interaction with their student. PSTs attended to task structures, learning goals, verbal explanations, semiotic actions, gamified features, and situated context. For example, PST B reflected on her student's understanding of task structures:

> Something I noticed while asking him about the game is that...when the game changed from a result unknown problem to a change unknown problem, he recognized that shift in mathematical concepts.

Since there are various levels in one task, students should be engaged in multiple problem structures with a similar context. PST B attended to this transitioning of tasks and the mathematical structure of the Pie Monster task.

Interpreting Children's Thinking

Interpreting includes reasoning about children's strategies and comprehending their understanding based on details (Jacobs et al., 2010). PSTs' initial interpretations focused on how children might make sense of the tasks, what mathematical concepts they might engage with, how they might make a connection between a concept and the ST Math representation, and what prior knowledge might be required. For example, Group C anticipated a possible way to use sense-making when students solve the Pie Monster task: "Some kids might know how to visually play the game but not understand that they are actually doing subtraction." This group of PSTs anticipated that students might use the visual representations to solve the task without understanding the embedded mathematical concepts (e.g., subtraction).

In the reflection paper, PSTs' interpretations of student thinking included descriptions of how students solved the tasks, how they engaged with different representations, and how the sequence of the tasks impacted students' approaches. For example, PST D noticed the progression of her Math Buddy's strategies. The students used a guess-and-check strategy at first, but this strategy had changed to a counting strategy over time:

> She was beginning to use other strategies that weren't simply guess-and-check, such as counting on. She counted the red circles, then found that amount in the yellow circles. She then counted the yellow circles that were left to find the answer.

PSTs articulated how students' solutions to the ST Math tasks, including their actions and explanations, revealed evidence about their understandings.

PSTs' Evaluations of ST Math

Our data revealed that PSTs' evaluations of the ST Math activities were, in some cases, more negative after engaging in them with students. In other cases, they were more positive, and in the other cases, the evaluations appeared similar.

Increased negative evaluations. Seven PSTs had a positive evaluation based on their initial explorations, but during their interactions with children they began to question whether some features were likely to foster mathematical thinking relevant to targeted concepts. For example, PST E was positive about the potential of the How many Petals? task to develop place value concepts (Figure 3). The major mathematical idea in this task is to recognize 10 petals are the same as 1 flower and 10 flowers are the same as a bunch of flowers.

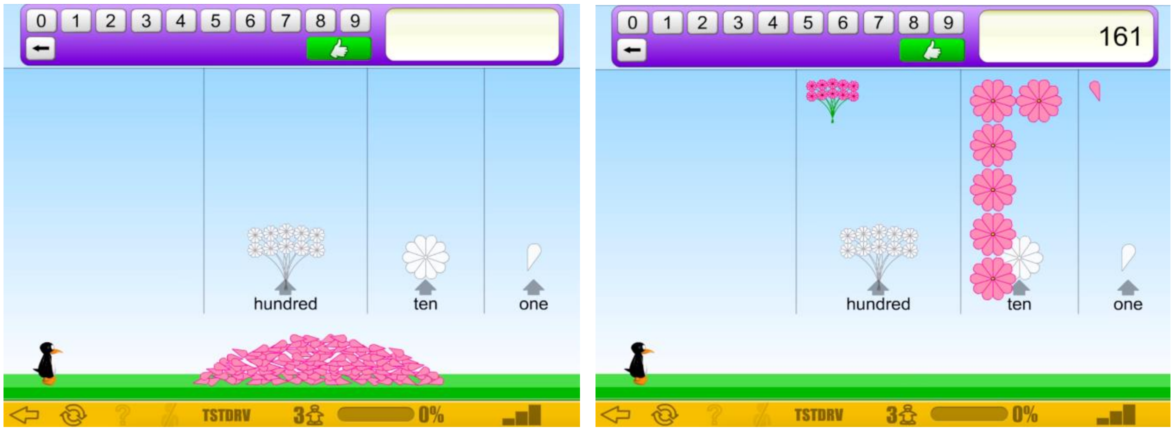

Figure 3: Problem Solving of the How many Petals? Task

PST E believed that the task could provide an opportunity to learn place value concepts (e.g., hundreds, tens, ones): "I think that the students can learn that they need 10 petals to make a flower and that they need to know how many flowers they have." However, he noticed that his student was able to get the right answers by just tapping the columns repeatedly, and did not demonstrate an understanding of the relationship between different places.

> *PST E*: [Before solving the second problem] So on this one you explain all your thinking out loud and how you do it. So, what's the first thing you do?
> *Math Buddy [MB]*: So, like if there is a big pile you press tens. These are all tens. And then or if you have not enough tens press ones.
> ...
> *PST E*: [At the third problem] Basically you just keep pressing tens until you run out.
> *MB*: Yeah.
> ...
> *PST E*: [At the final problem] What are you learning on this game you play? So, what do you learn when you do this?
> *MB*: I don't really know.

Even though the student completed the task successfully, he was not sure what he was learning from the ST Math activity. PST E noticed this lack of understanding of the mathematical concept:

> My understanding is that my buddy just counts the petals and that's it. You can even hear him clicking on the tablet screen rapidly to get rid of as many petals as you can. To me, there isn't much learning going on during this game, other than being able to identify where the hundreds, tens, and one's value is.

Initially, PST E believed that tapping the counting button could help develop an understanding of the relationship between ones, tens, and hundreds. However, when working with his Math Buddy, he noticed that the student was able to mindlessly tap the button until the solution was represented as a number of bunches, individual flowers, and petals. This made him evaluate the ST Math activity negatively ("isn't much learning going on").

Increased positive evaluations. Two PSTs had the opposite shift from a negative evaluation of ST Math to somewhat more positive evaluation, though these were sometimes the result of relatively sophisticated reasoning. For example, PST F initially criticized the *How many Petals?* task, anticipating that students might not use mathematical thinking: "The kids do not really have to do much thinking; they just need to memorize the different flowers." However, after she saw her Math Buddy demonstrate strong understanding in her explanation for why certain ones go in the tens column and others in the ones column, her evaluation was more positive:

> This leads me to believe that she was thinking mathematically rather than just playing the game without thought… I think that she does better at ST math because it is easier for her to visualize, as she uses direct modeling as her primary strategy for solving problems… I do not think ST Math should be discounted, it seems to be a big help for students to refresh on previously learned material.

PST F modified her evaluation of ST Math, focusing on its potential to "refresh on previously learned material." Indeed, the child appeared to be bringing her understanding of place value concepts to the task rather than developing it through the activity. The PST noticed this, and remained negative about its potential to "help students learn new material." Though the PST's evaluation is somewhat softened, we argue that the response shows a fairly sophisticated evaluation that includes some skepticism despite the child's "success."

Consistently negative. Our analysis showed three PSTs remaining consistent in their evaluations of ST Math. For example, PST G initially expressed the concern that her Math Buddy might use only an unsophisticated "counting by ones" strategy, "Because they can always count single units within the 10 petals, so as long as they can count by 1's they can finish the levels." When working with her Math Buddy, however, PST G noticed that the student focused on getting a right answer only without considering other strategies: "She seemed to just pick up patterns of how to pick out the correct answers and numbers to move to the next problem…. I do not believe that there is any strategy of solving the problem besides counting."

PST G was also worried about her student's misconceptions since it was possible to get the correct answers without understanding the base 10 structure of the petals representation: "It also may give students the impression that they understand the content just because they are able to find the pattern of the game and fill in the rest of the answers."

Consistently positive. Only one PST was included in this category. This PST kept evaluating ST Math positively. For example, she expected her Math Buddy to understand and use the relationship between multiplication and division embedded in the given pictorial model (e.g., dots, boxes) in the Building Expressions task (Figure 4). She initially appreciated the potential of the tasks, writing, "Students get to see a visual representation of every step of the multiplication and division process, furthering their understanding."

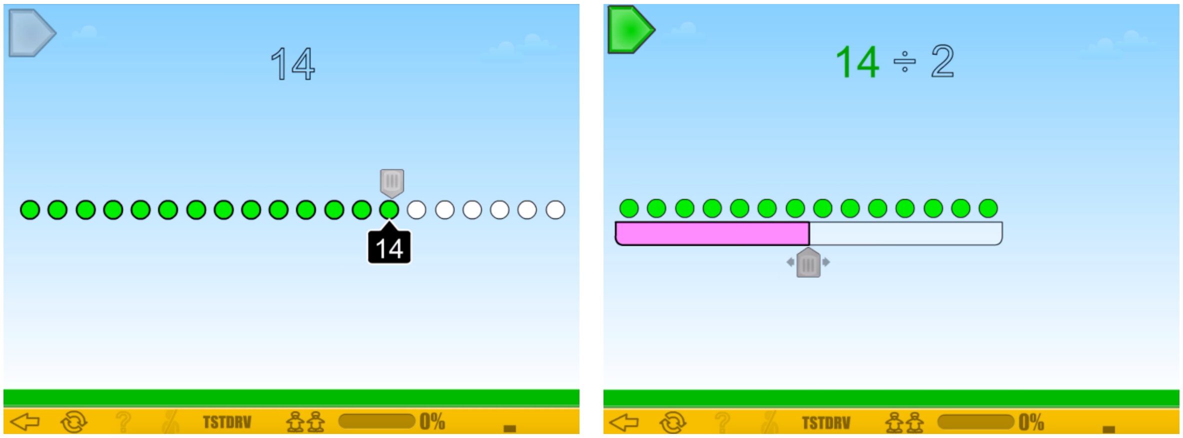

Figure 4: Problem Solving of the Building Expression Task

During the interview, PST H noticed her Math Buddy expressing more of his understanding with ST Math tasks, and eventually concluded that ST Math could provide good opportunities for children to engage in mathematical concepts and thinking: "When working with my Math Buddy I realized that ST Math reveals more about his thinking and understanding than story problems…This allows him to focus on showing his understanding of multiplication and division, or any other concept he is working on, instead of focusing on the words in a word problem." Perhaps because her Math Buddy was an emerging English Language Learner, the PST interpreted his work in ST Math as evidence that the visual representation could support his mathematical understanding better than story problems.

Discussion

In this study, our data show PSTs' attending to and interpreting student thinking during the use of ST Math tasks. Furthermore, we saw evidence of PSTs' drawing on their noticing of student thinking in their evaluations of the ST Math tool, in some cases coming to different conclusions from their original evaluations, prior to working with students (e.g., PSTs E and G). Often, these conclusions were based not just on whether children were able to complete the tasks and answer with correct answers, but rather how they were thinking about the mathematical ideas embedded in the tasks (Dick & Hollebrands, 2011; Pea, 1985). This raises the possibility that developing noticing skill, in general, might help PSTs be better consumers of technology, especially if they are asked to evaluate tools while simultaneously attending to student thinking.

Notably, many PSTs were positive about the *Building Expression* task after the exploratory activity, explaining that the task seemed accessible and helpful in developing the concept with broken-down visual models. However, most changed their evaluation after engaging with students and seeing them struggle to make sense of the connection between the symbolic and quantitative representations. One possible implication is that interactions with real children, with whom PSTs have relationships, can stimulate critical reflection on the value of learning experiences, including those involving new technologies.

We illustrated PSTs' attending and interpreting using example of ST Math tasks. These data extend earlier studies (e.g., Smith et al., 2018) to use field experiences in elementary schools for the development of technological noticing skills. We were encouraged to see several PSTs take a critical perspective on the use of technological resources based on their noticing of children's mathematical thinking. We believe that starting with a tool (ST Math) that preservice teachers see in their placement classes increases the relevancy of the activity, and helps us better understand how noticing children's thinking influences their evaluations. We also realize the limitation of this single case would not represent all technological resource and need further studies to investigate the impact of different types of tools.

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